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The Natural Sciences and Mathematics

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INTRODUCTION

THE manuscripts that have been submitted for this issue of the REVIEW exhibit two outstanding facts relating to research in science and mathematics during the past three years. The first of these relates to the total amount of research reported during this three-year period as compared with that of the three years ending in 1942. When the bibliographies for the seven chapters of this report are compared with those for the corresponding topics in the 1942 REVIEW, it will be seen that the total number of references for the 1942 issue was 402, as compared with 241 for the present issue. This fact would be disturbing were it not for the many disruptions caused by the war.

A second and more hopeful fact, which has been pointed out by several of the contributors to this issue, is that while the total number of studies is less than that of three years ago, there are more truly excellent studies represented in the present bibliographies. If the appearance of these excellent studies is an indication of the maturity of the scientific study of educational problems, this is promising indeed. Perhaps even the paper shortage may be contributing something of value in making it impossible to print some of the more trivial studies which scarcely deserve classification as research.

As will be seen from the table of contents, the committee in charge of this issue of the REVIEW has purposely followed the main classifications used in the 1942 number. This is due, in part, to the committee's opinion that the 1942 issue gave an effective treatment to the material, and partly to the fact that following a similar organization facilitates reference from one report to the other.

The committee is indebted to three contributors who were not members of the committee, but who assisted in the preparation of material. Charles C. Weidemann, who was originally a member of the present committee, asked to be relieved on account of ill health, and his withdrawal was accepted with regret.

The authors of the various chapters have aimed to be selective in their choice of materials rather than to include all published studies bearing on their topics. Even so, there will appear some references which, in the minds of certain readers, may seem to be out of place in a review of research. In some cases these questionable studies are included because they carry the implications of other research or give mature, critical evaluations of research; and in other cases, as certain courses of study, because they reflect rather well the extent to which scientific research has affected the organization of teaching materials. Practically all of the references included are of American origin. Under the conditions of war, no review of foreign research was feasible.

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CHAPTER I

Teaching of Science in Grades I thru VI

FRANCIS D. CURTIS

ONE who surveys the published research in the teaching of science in the elementary school published during 1942–44, can scarcely fail to be impressed with the exceptionally small number of reports of investigations as compared with the output in previous equal periods; and with the unusually large proportion among these of major contributions. Of interest, also, is the fact that a majority of the published studies under consideration are learning studies.

The Nature of Children's Explanation of Phenomena

The value of challenging and testing, thru research, results announced by earlier investigators is shown in a study by Oakes (6) which puts in question several theses previously announced by Piaget, and now widely accepted. Oakes (a) analyzed the nature of children's explanations of various natural phenomena, presented as simple experiments or as verbal questions, (b) compared these explanations with those given for the same experiments by adults, and (c) analyzed the responses as to types of explanations. He wished especially to study the extent to which children use animistic, mysterious, magical, or other nonphysical ideas to account for natural phenomena.

To 77 kindergartners, 24 other children from each of Grades II and IV, 28 children from Grade VI, and 35 teachers of nonscience subjects in a liberal arts college, the investigator presented fifteen problems as verbal questions and seventeen as simple demonstration experiments. The subjects were interviewed individually in a separate room, the experimenter making notes of their responses. He later categorized these responses in various subdivisions under the headings physical (materialistic), nonphysical (nonmaterialistic), and failure to explain.

Of major importance was the finding that most of the responses were naturalistic, a result at variance with certain theses of Piaget. The experimenter found, moreover, no evidence to corroborate Piaget's contention that there are definite stages in children's thinking which are characteristic of any given age. The differences between the responses of the children and those of the adults were found to be chiefly quantitative.

An important implication of this study is the practicability of and the need for training children from the beginnings of their schooling to seek naturalistic explanations of the phenomena they observe.

Children's Ability To Interpret Experiments in Terms of Generalizations

Baker (1) reported an extensive study to determine (a) the ability of children in Grades III, IV, V, and VI to interpret experiments in physical science correctly; (b) their ability to formulate generalizations; (c) the differences in their interpretations due to differences in mental age; (d) sex differences in ability to interpret such experiments; and (e) the factors affecting interpretation. The investigator demonstrated before each class separately fourteen experiments which together illustrated six different scientific principles. The 201 children individually wrote answers to the question, "What happened and why did it happen?"

From his results Baker concluded that children of both sexes are equally able to interpret such experiments; that this ability increases with mental age; and that the success in interpreting demonstrations depends upon such factors as kinds of apparatus used, order in which the experiments are presented, and familiarity with related phenomena.

Probably of chief importance in this study is the evidence which justifies the conclusion that children in the grades can formulate generalizations, or principles, from observations. This conclusion corroborates that arrived at earlier by Haupt and Croxton and adds corroboration of the practicability of the programs advocated in the *Thirty-first Yearbook of the National Society for the Study of Education* and in *Science in General Education*. An important implication is the responsibility of the teacher to make herself competent to direct the elementary-science experiences toward developing skills in observing phenomena and in formulating scientific generalizations.

The Sources of Information Used by Children in Solving Problems

An important contribution is the careful and extensive study by Bergen (2) to determine (a) what sources of information children tend to use or to suggest in attempting to solve problems; (b) what is the effect of the teacher upon children's selections of sources of information; (c) what sex differences are evident in such activities; and (d) what is the relationship between the kinds of sources which children suggest and the difficulty of the problem.

The investigator made running records of the classroom discussions of regular science lessons in five third-grade classes in two schools. She followed these observations with interviews with these children, and as a basis for comparison, with children of Grades I, III, and IV from a school where no regular science was taught. In these interviews she used questions designed to reveal how the children would and did find out. She analyzed responses to 199 problems.

The findings indicated that the children employed both empirical and authoritarian sources of information, chiefly books, and that the sources suggested for the more difficult problems were likely to be authoritarian.

The suitability and accessibility of the sources influenced the responses. The influence of the teacher was evident. The responses by the two sexes were not characteristically different.

The investigator points out the desirability of the teachers' making the children aware of their abilities and limitations, as a means of helping them to learn to choose appropriate sources of facts to solve their problems. Also, she emphasizes the great importance of the teachers' being alert to provide opportunities for the children to solve problems empirically. She stressed, as did Oakes (6) and as did Craig and Robertson, earlier, the need for elementary teachers to be better trained in the subjectmatter of the physical and biological sciences.

Difficulties Encountered by Teachers of Elementary Science

Quaintance (7) reported a questionnaire study of the problems encountered by teachers in carrying out a statewide program of elementary science. Many difficulties were listed by the approximately five hundred respondents. These indicate unmistakably that the teachers as a group lacked the necessary subjectmatter preparation to conduct the course successfully or with satisfaction to themselves. Most of the difficulties which they reported would not have arisen if they had possessed an adequate command of the physical and biological materials appropriate to elementary science.

Study Methods

Krause (5) reported an "equivalent groups" study with fifth-grade classes, to determine the effectiveness of having children write out answers to questions, as compared with having them formulate a new type test covering the same subjectmatter. Since the statistical treatment of the data could scarcely be deemed adequate, the chief value of the study would seem to lie in the emphasis it gives to the advantages to be gained from adding a new study device, such as test-making by the children, to procedures already employed.

Course Materials

Gilbert (4) reported an analysis of the topical content of seventeen state and thirteen city courses of study for elementary science, which is similar to the study of thirty-six courses of elementary science and nature study reported by Hillman in 1924. The investigator found, as had Hillman, a lack of agreement with respect to the science topics that should be studied, and with respect, also to the grade placements of the various topics.

The significance of any study of modern course content in elementary science in terms of topics may be questioned since the important developments in this field lie in the direction of effecting understandings of principles, developing scientific attitudes, and encouraging reflective thinking thru problem solving.

A monumental study by Curtis (3) indicated in elaborate detail the science known and practiced by a certain tribe of Indians. Unfortunately the extensiveness of the data probably will prohibit their publication. The study should nevertheless, exert a salutary influence toward encouraging the study of Indian life in all sections of the country as a source of elementary-science activities.

Concluding Comments

Summarizing statements cannot readily be formulated from the study of so small a group of investigations. One however seems justified: there is cumulative evidence of the need for broader training of elementary teachers in the physical and biological sciences as a basic essential to a successful elementary-science program.

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CHAPTER II

Teaching of Mathematics in Grades I thru VI

WILLIAM A. BROWNELL

For the three-year period 1939-1942 a total of 142 research reports and critical articles relating to arithmetic in Grades I–VI were summarized in the October 1942 issue of the Review of Educational Research (10). The corresponding total for the past three-year period is eighty-two. This latter figure is to be compared with the total of forty-nine studies listed by Buswell for approximately the same period in his three more rigorously selected annual bibliographies (13). The discrepancy is explained by the fact that in the present summary a larger number of articles of a theoretical and practical nature are included because of their value for stimulating new research and for improving classroom instruction.

COURSES OF STUDY

According to the *Education Index* five states published new courses of study in arithmetic. These were: Florida (21), Idaho (30), Kansas (36), New Mexico (45), and Vermont (68).

The Chicago city course of study, which received considerable publicity at the time of its appearance because of its frank espousal of a rather extreme stepped-up curriculum, was the object of both favorable and unfavorable criticism. Johnson (34), who was largely responsible for the course of study, presented evidence in the form of test data obtained in 1938, 1939, and 1940, to show steady improvement in learning under the new course of study. Chandler (16), on the other hand, noted numerous shortcomings in the course of study. Among them were the need for suggestions for enrichment and for guides to teachers, the need for less emphasis upon abstract computation and for more emphasis upon meaningful approaches, a reconsideration of the placement of topics grade by grade, and lack of agreement with adopted textbook series.

HISTORICAL STUDIES

Sueltz (62) observed that Adams, in his *Scholar's Arithmetic* published 125 years ago, addressed the learner in terms much like those used today, urging him to understand everything as he went along and to do everything possible for himself. Willey (78) traced the developing interest in the arithmetic in the out-of-school life of children, beginning with the work of Binet in 1890 and of Phillips in 1897. In another study, Willey (76) showed in brief historical outline the decline of drill and the rise of arithmetic as a social study.

An elaborate series of historical studies was reported by Smith and Eaton (52, 53, 54, and 55), who summarized their findings, with Dugdale,

in a single bulletin (56). Their procedure consisted in the measurement of space devoted to arithmetical topics and processes in textbooks, of which there were eight in the period 1790–1820, twelve in the period 1821–1850, sixteen in the period 1851–1880, thirteen in the period 1881–1910, and ten in the period 1911–1940. To the extent that arithmetic as a school subject can be appraised by their research technic, these authors in their reports provided the best single account of detailed changes which have occurred in the past six and a half decades.

NATURE OF THE LEARNING PROCESS

Brownell (5), writing on "The Progressive Nature of Learning in Mathematics," called attention to four kinds of instructional shortcomings which, if not traceable to, are at least consistent with connectionistic conceptions of the learning process. These shortcomings are: (a) the tendency to stress the product of thinking (rate and accuracy of response) with a corresponding neglect of interest in the pupil's procedure; (b) the setting of too rapid a pace in learning, accompanied by failure to furnish children temporary aids which they need if they are to learn meaningfully; (c) the prescription of wrong kinds of practice (e. g., repetitive drill when varied experience is called for); and (d) superficial diagnosis and inappropriate types of remedial teaching. Drawing upon data from previously published research reports, the same author showed the contribution of a particular device (crutch) in the case of borrowing in subtraction (7) and, with Carper (9), traced the course of learning in one arithmetical function (the multiplication combinations) thru the use of group test scores and thru the results of individual interviews.

THE CURRICULUM

Vocabulary Studies

Rolston and Spitzer (51) investigated the extent to which the word "and" is and is not used in connection with oral and written numbers involving three or more figures. In spite of the unanimous recommendation of arithmetic textbooks and books on the teaching of arithmetic that the word "and" be omitted in reading and saying such numbers, they found "and" used in 60 percent of the possible occasions on radio programs and in 54 percent of the cases by twenty-six authors, and in three encyclopedias and six dictionaries.

Willey (79) reported arithmetical terms and phrases used by children in solving the problems of their daily lives—or, rather, as found in the teachers' transcriptions of their pupils' reports. A table was prepared containing about ninety words and short phrases which occurred ten or more times, classified by grades—kindergarten and Grades I and II, Grades III and IV, and Grades V and VI. The author called attention to various factors which in part invalidate the findings as reported.

Measurement

Using twelve third-grade texts, Gunderson (24) undertook to find the amount and kind of measurement expected of children on entering this grade, as one means of determining the corresponding information to be imparted in the lowest two grades. Tables were presented to show the units in each of the common categories of measurement and the space given thereto in the various texts, the percents of book space allotted to this kind of matter, and the amount of space devoted to miscellaneous measures, such as bar, basket, box, etc.

Yorke (82) reviewed three studies, the last one her own, on the extent to which metric units are used in countries where the metric system is legally compulsory. Her own data were secured in the course of visits to four South American countries. There she found that 65 percent of measurement uses reflected acceptance of the metric system, and, 35 percent did not. There were wide differences in the extent to which the metric system was employed, the rural areas, for example, being much more prone to continue with traditional units. Her conclusion was that, on the basis of these facts, there is little argument for teaching the metric system in the United States for purposes other than those of information.

Out-of-School Uses of Arithmetic

Employing teachers in the kindergartens and in Grades I–VI in Santa Clara County, California, Willey (75) collected a total of 2484 problems "which arose in the life of the children and which seemed to have arisen spontaneously out of natural situations." (His data were reported also in reference 77.) The children's problems were analyzed in various ways, and his tables contained classifications (a) according to twelve arithmetical categories (counting, common fractions, subtraction, and so on) by grade level, and (b) according to fundamental operation employed (addition, subtraction, and so on). His findings differed considerably from those reported earlier by other investigators, a fact which may mean that such studies are of limited value, being chiefly useful in the areas in which they are made. One recommendation was that all processes, including concepts now reserved for the higher intermediate grades, should be introduced in earlier grades to allow time and opportunity for their meaningful development.

A somewhat similar study was made by Ellsworth (18), who had 390 children in Grades III–VI in an urban area check daily those of seventeen listed arithmetical topics which had served any useful function in their lives. The uses were then classified. Telling time led the list (27 percent of the total), followed by using money (15 percent), counting (14 percent), and so on, to adding fractions, measuring areas, and dividing, subtracting, and multiplying with fractions, none of the last named five topics contributing as many as 1 percent of the total.

Roberts (50) had 219 unselected employees in various industrial organizations in Houston check a carefully prepared questionnaire, based

upon textbook problems, to find the extent to which they used integers and common and decimal fractions. His classifications revealed that 80 percent of the employees "frequently" (once a week) added four-place numbers, 50 percent "frequently" added five-place numbers, and 34 percent "occasionally" (less than once a week) added six-place numbers. Corresponding types of data were tabulated for other arithmetical units and processes. Recognizing that social utility is not the sole criterion for determining the content of the arithmetic curriculum, he nevertheless urged the making of similar studies with other groups of the population.

Grade Placement

The grade placement of arithmetical topics was the main concern of only two investigators. If this subsidence of interest in this phase of curriculum construction means a general complacency with the stepped-up placement which has become generally accepted in the past two decades, the lack of research is to be deplored. If, on the other hand, it means that investigators are getting ready to attack the factors which are basic to sound grade placement, the lack of research dealing directly with grade placement is a healthy sign.

As noted above, Johnson (34) presented evidence which he interpreted to mean that the stepped-up curriculum in the Chicago schools had proved to be a success. Ulrich (66) analyzed eight textbook series for Grades III–VI, together with their accompanying materials for the first two grades, all published since 1937. His first table summarized the placement of twenty-four topics. His second classified the topics, broken down into details, to show the place of their introduction under the headings "common agreement" (more than half the texts), and "wide variation." It is impossible here to list Ulrich's findings, and the interested reader must be referred to the original source.

Readiness

Associated with the problem of grade placement is that of readiness. Wittich (81) described a readiness test prepared in his system for administration to children entering the first grade and reported data showing typical responses and illustrating the usefulness of the test. Souder (57) announced the construction and evaluation of readiness tests for common fractions.

Carper (15) by careful observation and interview noted the extent to which children in the primary grades are capable of apprehending concretely presented numbers by the use of groups. Previous research had been limited, almost entirely, to counting activities. Finding that grouping was well within the powers of her subjects, she criticized primary grade courses of study and commercially prepared instructional materials for failing to utilize the developing ability and to encourage its further development as a preliminary to the study of the simple combinations. In another place (9) Carper reported data to show that a slightly retarded

group of third-grade children who had had no instruction on the multiplication combinations as such already possessed a considerable body of knowledge about the process, which guaranteed successful results from instruction.

EVALUATION, DIAGNOSIS, AND REMEDIAL INSTRUCTION

The Stanford Intermediate Arithmetic Test was administered to 11,348 sixth-grade pupils in 468 schools in Indiana. Eaton (17) tabulated the results of this extensive survey, involving about a quarter of the total enrolment of the state in this grade, in a variety of ways: city schools, township schools, and special schools; relation of achievement to age of pupils, length of school year, number of classrooms per building, size of classes, size of schools, time spent on arithmetic, and so on.

To find "how the sequence and difficulty of examples affect the score a student makes on a test in division of decimals," Grossnickle (23) studied the test papers of 409 pupils selected at random from Grades VI–VIII. His tests were carefully prepared in the light of his purpose, and his data were well handled. He found that easy examples in the processes were as good for diagnostic purposes as were difficult examples, and he therefore recommended that test examples should be relatively simple and distributed at random with respect to type.

After years of experimental teaching, Fernald (20) described her remedial methods and reported on some of her pupils who were supposed to represent cases of "special disability" in arithmetic. In all instances use of concrete materials as a basis for understanding brought distinct improvement in achievement. The following sentence is especially important for those who ascribe difficulty in learning arithmetic to some shortage in heredity: . . . "there is no such thing as a child of normal intelligence who cannot do arithmetic" (p. 213).

Bemis and Trow (1) raised the important question: What happens after two years of remedial instruction? It has been rather generally assumed that, once a child has been enabled to "catch up" thru remedial teaching, he will proceed at a normal rate. This comfortable belief was rudely shaken by the data in this study, for the results of remedial teaching were found to be exceedingly variable. The authors offered as an explanation a corresponding variety in the maturation level which had been attained by the pupils at the start of remedial work. Another explanation, equally as tenable, is that the type of remedial instruction, which seems to have been drill, was variously appropriate to the needs of the children subjected to it. Whatever the explanation, Bemis and Trow demonstrated the need for suspending judgment as to the worth of remedial efforts until more data are in.

MEANING IN ARITHMETIC

A lengthy bibliography for the past three-year period could be assembled under the caption above. Only a few of the many possible references can be mentioned here.

In general, it may be said that at present there is agreement that arithmetic must be taught meaningfully, tho there are wide variations both in theory and practice with respect to the meanings which should be taught and to the procedures by which they may be developed. Buell (12) was one of the few to raise objections to the trend toward greater emphasis upon meanings. Wheat (72) undertook to refute Buell's criticisms in an article which dealt with: What is meaning in arithmetic? Can pupils grasp meanings? What good is meaning in arithmetic? Tho not written with specific reference to Buell's strictures, Mossman's article (44) may be regarded as in the same category as Wheat's. At greater length than either of the two writers just mentioned, Brownell (8) analyzed the essential meanings of arithmetic which must be taught, considered the objections to the teaching of meanings, and offered reasons why meanings should be developed.

In a series of articles Riess (47, 48, 49) discussed the growth of meaning in the early phases of arithmetical learning; and Van Engen (67) set forth in an able manner the value of what he called "unifying ideas" in arithmetic instruction. Among these unifying ideas are: regrouping in addition; grouping by tens; positional notation; relations of fundamental operations; relation between common fractions, decimal fractions, and percentage; dependence, proof, approximation, and error in measurement. Particularly challenging was his demonstration of the way in which one idea, namely, $7 + n = 13$ (instead of $7 + ? = 13$), permeates the whole of mathematical thinking.

A number of articles described illuminating experiences in the development of meanings. Spitzer showed the usefulness of the abacus in exploring number meanings in our decimal system of notation (58), and, for a similar purpose, the use of what he called a "ten block" for the construction and identification of two-place (and larger) numbers (59). Steiss and Baxter (61) reported how they developed number meanings with concrete materials, and Spitzer and Dunfee (60) told how to teach the multiplication and division facts in a meaningful manner. MacLatchy (40) explained the usefulness of "markers" in teaching numbers, and, with Hummel (41), gave an informal account of the procedures employed in meaningful teaching with a small group of children in Grades III and IV.

Those interested in the improvement of classroom instruction will do well to consult all the references mentioned above. They should also study Wheat's excellent monograph (71) which is treated below and read carefully the report of the special ASF and U. S. Office of Education committee entitled "Essential Mathematics for Minimum Army Needs," [1] a large part of which is devoted to problems of teaching important arithmetical meanings.

CRITICAL APPRAISALS OF CURRENT PRACTICE

Buswell (14) in a stimulating discussion pointed out five major weaknesses in arithmetic programs: (a) failure to appreciate the value of

[1] See reference (14), Chapter VI.

an abstract use of number in meeting the needs of life (it is sound practice to *start* learning with the concrete, but an error to *stop* it at this level; instead learning must be carried thru to the abstract); (b) lack of ingenuity and insight in devising socially significant illustrations to make arithmetic interesting and to show its relation to life experiences; (c) deemphasis on arithmetic in the supposed belief that damage is necessarily done to personality by systematic instruction; (d) neglect of noncomputational uses of arithmetic, as in reading and in quantitative thinking; and (e) errors which arise from the attempt to limit the arithmetic program to the "natural" experiences of children.

Bond (2) wrote helpfully on the need of establishing a proper balance between social arithmetic and a science of arithmetic. He pointed out that the former overemphasis on computation has brought the inevitable counter-reaction with social uses now receiving the major share of attention; and he argued, not for an abandonment of social uses, but for the incorporation of these uses into a program which will result in a real apprehension of arithmetic as a science.

STUDIES OF TEACHING AND LEARNING

One of the important publications in this area was Wheat's monograph (71) in which he summarized and integrated the findings of studies by his students, three theses and forty "problems," the latter described as being "somewhat less quantitative" than the theses but frequently "more closely related to actual classroom work." The studies were grouped under "Teaching Methods of Self-Instruction" (twelve studies), "How to Teach and What to Teach" (nine studies), "Problem Solving" (six studies), "Vocabulary of Arithmetic" (two studies), "Difficulty of the Combinations" (perhaps more accurately, difficulty of the processes, two studies), "Managing the Practice" (four studies), "Helping the Retarded Pupil" (four studies), and "Miscellaneous" (three studies). The various investigations are not treated separately here, partly because of space limitations but chiefly because much of their value lies in the orientation and excellent interpretations supplied by Wheat in the monograph itself. The reader should also be able, from the chapter titles just mentioned, to add the Wheat monograph to the bibliographies appropriate to topics already discussed above (e.g., vocabulary studies) and to be discussed below (e.g., problem solving).

Problem Solving

Johnson (31) brought together, summarized, and criticized the thirty-nine published reports of investigations on problem solving, under the heads: (a) causes of difficulty, and (b) improvement of problem solving (relative effectiveness of six different types of attack which have been studied, relative difficulty of various types of problems, relation of practice exercises to success in problem solving). In spite of the fragmentary, inconsistent, and frequently inconclusive nature of research findings in

this area, Johnson expressed himself as optimistic about the possibilities of further research on problem solving.

Hall (25) found it effective to have pupils, working with their own problems, read and discuss them orally, select the appropriate operation in group work, and estimate the approximate answer before solving. His subjects, all taught by himself, were three Grade V and three Grade VI classes.

Hansen (26) administered a total of nine arithmetic tests, ten mental tests, and seven reading tests to 681 sixth-grade pupils. He then compared the 184 best pupils in problem solving with the 184 poorest in problem solving, finding the former superior in all tests except the four Gates reading tests. His announced purpose was to discover "factors associated with successful achievement in problem solving."

Using 898 pupils in twenty-eight seventh-grade classes taught by fifteen different teachers, Johnson (32) undertook to measure the effect of instruction in mathematical vocabulary. Comparing test scores of his control group and of his experimental group (to whom selected technical terms were carefully taught), he found no reliable difference in any part of the Analytical Scales of Attainment, a reliable difference favoring the experimental group on vocabulary tests containing the words taught them, no difference on a test of transfer in learning vocabulary, and superiority for the experimental group on two of his specially prepared tests in problem solving.

Klugman (37) reported that children working together were more successful in solving problems than were control children who worked alone. His pairs were carefully matched for sex, race, grade, CA, and IQ.

Sutherland (63) gave a battery of thirteen tests to 352 children aged ten and eleven. The mean scores made on problems with familiar settings were higher than those on problems with unfamiliar settings. Statistical analysis yielded five factors of importance to success, three of which he identified as *g*, a verbal factor, and a number factor, all apparently equal in potency.

Another elaborate testing and statistical study was made by Treacy (65), in the attempt to learn the relationship between reading skills and problem solving ability. In all, he administered thirteen reading tests, purportedly measuring as many different skills, together with tests in problem solving and in general mental ability. The eighty best achievers in problem solving were compared with the eighty poorest, and the results showed reliable differences in quantitative relationships (scarcely reading at all), vocabulary in context, perception of relationships in content, and integration of disparate ideas. Nearly reliable differences were found in arithmetic vocabulary and in four other reading skills. Having demonstrated markedly dissimilar degrees of relationship between different kinds or aspects of reading (on the assumption that the tests were valid) Treacy drew the somewhat surprising conclusion that future research on his problem must deal with reading as a single unitary ability.

The Simple Combinations

Swenson (64) showed that the difficulty ratings of addition combinations vary with learning method, and so added new evidence that these combinations (and others, by inference) possess nothing which can be called "intrinsic" or "inherent" amounts of difficulty for learning. Wilburn (74) published convincing data to show that a method of self-instruction taught his subjects enabled them to master the addition combinations with relative ease.

Two studies relating to the multiplication combinations appeared. The one, by Wheeler (73), involved 342 children in Grade III who were required to learn the combinations thru playing his game, Mult-O, a drill device. The degree of success attained was slight, a fact which the investigator attributed to the shortness of the experimental period. Brownell and Carper's monograph (9), besides critically evaluating previous research on the multiplication combinations, reported two new studies with large but different school populations, showing the changes in learning which occur in rate, accuracy, and quality of thought process from Grade III-A to Grade V-A (the last-named data having been collected by interviews). The monograph also includes new data on readiness previously alluded to (see the topic Readiness above) and a discussion of problems of learning and teaching in the case of these combinations.

Division

Holland (28) analyzed thirteen sources of difficulty in this process and gave four sets of suggestions for making it easier for the learner. The value and suggestiveness of her discussion was enhanced by her evident experience in working with children on this process. Koenker (39) found that excellent achievers in two-figure division surpassed poor achievers by reliable margins in all aspects of general ability as well as in all specific factors relating to the process as measured by his tests. When the effects of MA and CA were statistically controlled, the superior achievers excelled in all factors except reading.

Grossnickle (22) made a careful analysis of errors in division of decimals, using one hundred papers selected at random over a range of grades. He found twenty-one classes of error, practically all of them "spurious" and "inconstant" (and not "persistent," as has many times been claimed), which he grouped under five main types: Errors resulting from placement of quotient (five subtypes, comprising 40 percent of all errors), errors resulting from shifting the point (five subtypes; 31 percent), errors resulting from O (five subtypes; 15 percent), errors resulting from combinations (four subtypes; 9 percent), and miscellaneous (two subtypes; 5 percent).

Concept Development

Employing tests to measure the extent to which concepts relating to common and decimal fractions had been developed, Johnson (33) reached

the conclusions that such concepts were only about 40 percent learned in Grades VI, VII, and VIII and that mental age was a stronger factor than was grade in determining the status of understanding which had been attained.

Organization for Instruction

Maguire (43) described how she correlated arithmetic into a unit dealing with citrus fruit, demonstrating that the alert teacher has no difficulty in arranging opportunities for children to use their arithmetic outside the class period. Harding and Bryant (27) showed the possibility of teaching arithmetic "thru functional procedures" and without recourse to systematic instruction on the subject itself. They presented data from an experimental class to show that pupils taught thru "activities" were fully successful in attaining the standards set for control pupils as well. Moreover, they indicated that the experimental children gained appreciably in personal and social adjustment.

RESEARCH IN ARITHMETIC

As has already been stated, Johnson (31) summarized the research done on problem solving and offered valuable criticisms. Knipp (38) analyzed the sixty-four published studies relating to the comparative merits of instructional procedures, with a view (a) to discovering trends in experimental interest, procedures used, and results obtained; also (b) to ascertaining whether there was any relationship between interest in the specific fields of investigation and reported results, or between procedures and results.

Wilson (80) called attention to the need for research on the skills, appreciations, and knowledge of arithmetic which are of demonstrable value, rather than upon items and processes for which no convincing case can be made. Using data from the study on the multiplication combinations mentioned above, Brownell (6) undertook to show the need to include in evaluation some evidence on the degree to which children are actually growing in power of quantitative thinking. His recommendation would mean more concern about children's processes as contrasted with the rate and accuracy of their products alone and would probably mean the more extensive use of such research technics as observation and the interview.

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CHAPTER III

Teaching of Science in Grades VII, VIII, and IX

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Problems Related to the Reading of Science

Two investigations of reading problems related to general science, those by Swenson and Shores respectively, deserve special consideration, because of the elaborate and careful statistical technics employed. Swenson (19) attempted to determine what differences and similarities exist among reading materials used in general and scientific material in their relation to rate, vocabulary, and comprehension. From the seventy-five best and the seventy-five poorest readers, selected from 217 eighth-grade pupils on the basis of their scores on a standard reading test and a battery of reading tests of science materials which she had constructed, the investigator matched eight groups on the basis of chronological age and mental age to provide a basis of comparison between good and poor readers with respect to various factors in general reading and in reading science materials. She computed T ratios "to indicate the probability of differences in the performance of upper and lower matched pairs."

The investigator found more evidence of similarities than of dissimilarities between science and general reading. She concluded that good readers measured in one type of reading test are likely to be good readers as measured by other types; that rapid readers of science materials are not significantly superior in comprehension of either science or general reading materials, or in science or general vocabulary; and that there are more likely to be differences between phases of reading skills, such as vocabulary and comprehension, than between science and nonscience materials.

Shores (17) investigated the relationships between certain reading and study skills and reading comprehension of science and history materials. Only the aspects involving the general and the science materials are considered here.

Using 380 ninth-grade pupils, the investigator paired groups on the bases of mental age and ability to read literature. He used the generalized matching-control technic of Johnson and Neyman to determine differences in mean ability in various measured skills.

His findings indicated that the ability to read science is significantly related to comprehension of history materials; knowledge of science vocabulary; knowledge of general vocabulary; ability to read graphs, charts, and tables; understanding of details; and total score on measured skills of silent reading comprehension. Like Swenson, Shores found the good readers of science materials superior also in the detailed and exacting skills of reading.

In contrast with Swenson's conclusions, however, Shores affirms that by the time pupils reach the ninth grade, their reading proficiency is largely specific to the content fields, and that the evidence from his study refutes the concept of general reading ability in the ninth grade. This variance between the conclusions from the two investigations furnishes stimulating evidence of the need for further research along these same lines.

Of special significance is the emphasis by both these investigators upon the need for every classroom teacher to be a teacher of reading.

Uses of Motion Pictures

Using 800 pupils in eighth- and ninth-grade general science classes, Krasker (8) compared the relative effectiveness of having motion-picture films viewed by small and by large groups when the pupils were permitted during the showing to take notes, ask questions, and contribute discussion; and compared the relative effectiveness of a "nonpreparation" and a "preparation" method. The latter consisted of a showing of the film followed by a preparation providing study of the film thru a list of questions based upon it, and then a second showing. Groups were equated "socially, educationally, and mentally." Five films were used in the second part of the investigation.

Of significance (despite incompleteness of the report), in view of the presentday practice of organizing large classes, is the finding that a higher degree of mastery of facts was achieved by pupils in the small classes than in the large ones. This finding is in harmony with that of Hurd in his earlier study of achievement in high-school physics. Of interest, also, is the conclusion that the mere showing of a film does not give a sufficiently satisfactory learning result to justify stopping the instructional activities in order to introduce it.

Jayne (6) reported a comparison of the informational gains from listening to a lecture, with those from seeing a silent motion picture presenting the same materials; and of the retention of informational gains from the two methods of presentation, over periods ranging from three to fifteen weeks. From a random sampling of 271 pupils, he secured two "equivalent" groups, each of five classes of general science. Choosing two films he constructed lectures from notes taken on repeated reviewings of the films. He used blackboard sketches and diagrams to illustrate each lecture, which was made to occupy the same amount of time as the showing of the corresponding film. The rotation method of investigation was used and the results were determined from critical ratios based on standard scores on specially constructed tests.

The results both for immediate and delayed recall of factual information favored the lecture over the film. In view, however, of the relatively limited general use of the lecture method in the junior high school and the decreasing emphasis upon the mere learning of facts as an important aim of courses in science, the effect of this study would seem to be to

emphasize disadvantages resulting from the indicated use of silent motion pictures rather than to establish the desirability of teaching general science by the lecture method.

Of interest are the investigator's statements that the increase of factual learning gained from visual materials is due primarily not to the visual experiences solely, but to the combination of the visual experiences and other teaching procedures; that, as may be inferred, also, from Krasker's conclusions, teachers are not justified in eliminating other types of experience in order to show films; but that the best results are likely to be obtained from a combination of films with all other teaching methods and devices.

Uses of Illustrations in Textbooks

Kambly (7) reported a unique study, partly involving general science, in which he attempted to discover whether pupils "study or even look at" the illustrations in their textbooks, and whether the proper use of illustrations by pupils and teachers contributes to pupil achievement. He administered to two groups each composed of three classes in general science, a test of items of information derived from the illustrations in a three-week unit of text material. One group then studied the materials in the text; the other studied the same materials in mimeographed form. Conditions within both classes were kept as nearly uniform as possible during the experimental period at the end of which the test was again administered to both groups.

The findings showed a "significance ratio" of 1.97 in favor of the group that had had access to the illustrations, tho approximately half these pupils were unable to answer accurately, questions about them. The evidence indicated, also, that illustrations when "properly used by pupils and teachers do contribute to pupil achievement."

The study should stimulate textbook authors and classroom teachers to make more definite uses of illustrations. The investigator affirmed that this objective evidence indicates "that teachers must help pupils to learn to study the illustrations in their textbooks."

Aspects of Problem Solving

Teichman (20) attempted to determine the effectiveness of a problem-solving technic in teaching ninth-grade pupils to state inferences from given facts, to select the best conclusion from four proposed, and to evaluate proposed conclusions in terms of reasonableness, sufficiency, and pertinency of data. Eight classes served as experimental groups and twelve others as controls. The groups were matched on mental ability and the sums of standard scores on tests constructed by the experimenter to measure the ability to make conclusions. Conclusions from the study were based on standard scores and various coefficients of correlation.

As would be expected, the groups which received training in problem solving gained more than did the control groups. Also of significance is

the finding that pupils who were dull and were poor readers were nevertheless able to improve in ability to make conclusions.

The investigator concluded that, while pupils who are superior mentally and who possess superior reading skills prove more likely to show high initial skill in making conclusions, mental ability and reading skill are "very poor indications of ability to improve one's skill in making conclusions." Further, he states that the ability to state conclusions, to select the best reason for a conclusion, and to select the best conclusion from several are not identical abilities.

This investigation makes a substantial contribution to the study of scientific method and also adds evidence to the cumulative findings of a considerable number of earlier researches which indicate that far better results in attaining desired outcomes are derived from employing teaching procedures directed toward specific objectives than can be obtained concomitantly from attempts to achieve other instructional goals.

Curtis (1) reported a study to determine the types of questions demanding reflective thinking and the frequencies with which these various types were employed in recent general science textbooks and workbooks. The first phase resulted in determining sixteen distinctive types of thought questions. The second phase was the analysis into these sixteen types of the questions found in six textbooks and seven workbooks of general science.

It was found that most of the questions included in the materials analyzed represented in substantial numbers only a relatively few types. In the textbooks 84 percent of the thought questions were those involving explanation, recall, decision for or against, discussion, and cause and effect relationship. In the workbooks, the most frequently represented types were those involving recall and relationship.

The evidence led the investigator to the same conclusion stated by Cunningham in relation to his somewhat similar study reported in 1925, namely, that in texts and workbooks written for junior high-school science, insufficient use is made of many types of questions that stimulate reflective thinking.

A possible value of this study to textbook authors and teachers lies in its descriptions and illustrations of the various types of thought questions and the implication that all these types should be introduced into teaching materials and classroom activities.

Textbook Contents

Novak (11) added another analysis of the content of general science textbooks to the long list of such investigation that began with Howe's report in 1919. He estimated to the nearest quarter page, in nine texts, the amounts of space devoted to the various topics.

As would be expected, he found a wide variation in the amounts of space devoted to the same topics in different texts. Also, he arrived at the same conclusion with respect to the relative amounts of biological and

physical materials, that all previous investigators of the same problem, without exception, have stated, namely, that a considerably greater portion of the content of general science textbooks is devoted to physical than to biological science (65.5 percent as compared with 34.5 percent). The implications of this conclusion to authors of textbooks and constructors of curriculums are not clear, since the various attempts thus far reported to synthesize, statistically, the content of general science textbooks with other appropriate materials revealed by curriculum investigations of other sources, present in their resulting composite outlines a preponderance of physical over biological materials.

Values of Science Notebooks

Krause (9) reported an extensive study to determine whether the science notebook "can be taken as a valid measurement of achievement" and as a reliable basis for judging pupils' work in general science; and whether "the prevailing emphasis upon the notebook" is justified. After formulating criteria for writing and for marking notebooks, the investigator gave 249 boys in fifteen classes of seventh- and eighth-grade science careful instructions in "the various ways of writing a notebook," and practice in making and interpreting analytical drawings and in taking notes. He measured "acquisition of factual knowledge and general information," "development of a scientific attitude," and "ability to apply scientific facts, principles, and knowledge toward explaining common phenomena." He used sigma, or z, scores computed from scores on original and standardized tests together with weighted notebook scores as the basis for determining a series of coefficients of correlation.

From various findings, the investigator concluded that "there is little justification for the compulsory writing of a science notebook of the type investigated." This conclusion agrees with those arrived at earlier by Mayman and by Applegarth, but not with those announced by Baird and by Phillips. The implication seems plain, therefore, that much additional evidence must be obtained before the general and (more important) the specific values of pupil recordings of their laboratory experiences can be conclusively determined.

Integrating General Science and Algebra

A study by Gorman (2) compared the effectiveness of teaching integrated mathematics-science in the seventh and eighth grades with that of teaching the same materials in separate classes in these grades. The materials used were obtained from a survey of the content of textbooks of mathematics and of science. The work with the seventh-grade class was preliminary and preparatory. The actual learning study was carried on with two eighth-grade groups equated on the basis of "promotion quotient." The work was taught as a series of problems involving individual and group activities with integrated materials, to the experimental group; and with

the same topics in basic textbooks of science and mathematics to the control group.

The results of the investigation revealed no "appreciable" differences in the learning by the two groups. Great significance, however, can scarcely be attributed to this finding because of the incompleteness of the statistical treatment as reported, and because also of the small groups of pupils involved. Of interest, however, is the investigator's conclusion that it is possible to integrate, with topics usually included in seventh- and eighth-grade science courses, practically all the topics commonly presented in a course in seventh- and eighth-grade mathematics.

Materials for Course Enrichment

Studies of scientific interests as one basis of selecting course content, have been appearing in considerable number and variety since Trafton's pioneer study was first reported more than forty years ago. In a recent investigation, Sisson (18) sought to secure materials for constructing a seventh-grade general science course, from a study of the scientific interests of the pupils and of the scientific topics they best and least well understood. Unfortunately, the technics employed and the ways in which the data were to be used in course construction are not completely and clearly indicated in the report.

The investigator concluded that the scientific interests of pupils are not constant. This statement is in harmony with Fitzpatrick's conclusion and at variance with Zim's, from their earlier studies of the reliability of children's interests. The pupils were found to have more knowledge of physical than of biological science, and, apparently, (as was found in earlier studies by Pollock, Curtis, Craig, and Washburn) to be more interested in the former than in the latter. Of chief significance, perhaps, as an indication of the need for further experimentation, is the investigator's further conclusion that pupil interest centers in *aspects* of topics rather than in large topics.

Beginning with the pioneer study of *Biology in the Public Press* published by Caldwell and Finley in 1923, there have been frequent and varied reports of analyses of newspaper science. Novak (10) measured the length in column-inches, of the materials dealing with science which appeared in four years' issues of the *New York Times*. He found about one-fifth of the total space devoted to health and medicine; and about three-tenths more concerned with discussions of communication and transportation, animal life, man and behavior, and gardening and agriculture. The investigator found that during the entire period, practically equal amounts of space had been devoted to physical and biological science.

A "simple survey" by Relyea (12) was made of the articles read by pupils in seventh-, eighth-, and ninth-grade classes in connection with occasional "current-science days." The pupils were required to read and report upon scientific articles in periodicals, but the nature of their choices was

left to individual preference. An unsigned questionnaire was used to secure evidence relative to the nature of the articles and the student opinions of the values they thought they had derived from such reading.

Most of the articles dealt with medicine and disease, aviation, and chemistry. Perhaps the chief value of this study lies in its emphasis, in agreement with findings of earlier studies, upon values to be derived from extensive reading of general science.

Investigations such as the three just considered by Novak (10) Relyea (12), and Sisson (18) provide suitable materials with which to enrich courses of general science. They may be of greater potential value, however, as sources of data to be used in syntheses such as the ones by Robertson, Wise, and Martin, leading to the determination of scientific principles appropriate to courses of science.

Other Aspects of Junior High-school Science

Hunter and Parker (4) presented a phase of the latest of a series of extensive questionnaire surveys of science teaching, which the former has carried on from time to time over a period of several decades. Only aspects related to science in junior high schools are considered here.

The attempt to confine the presentation of even a small segment of so extensive a study to a few pages has prohibited the authors from presenting their data in a form which can be readily assimilated and evaluated. Perhaps the chief value of this report is the evidence it furnishes that the study of general science proves of considerable value to pupils who subsequently study more advanced science courses. This finding provides some confirmation of the results obtained fifteen years ago by Carpenter from his investigation of the relative success of pupils in chemistry and physics who had, and who had not studied general science.

In a report of another phase of Hunter's serial investigation, Hunter and Spore (5) stated that general science is most frequently offered thruout the country in the ninth grade of the junior high school. Hilgers (3) found that general science is taught "as a required course in grades seven, eight, and nine in practically 100 percent of the [277 Minnesota] schools."

Hilgers (3) found, also, that the following teaching methods were used in percentages ranging from 92 to 37 percent of general science classes in 277 Minnesota high schools: supervised study (92 percent); class discussion (90 percent); text assignment and recitation (88 percent); references and reports (87 percent); problem (63 percent); lecture (57 percent); and contract (37 percent).

Rumble (13, 14, 15, 16) contributed a series of reports, of which more may appear later, of the history of science at the junor high-school level. Three deal respectively with the Colonial Period, and with the periods from 1776 to 1827, and from 1827 to 1857; the fourth discusses the origin of junior high-school science.

Among the voluminous findings, are the statements that science materials at the junior high-school level were introduced into the schools "by

way of Morse's geography textbooks as early as the last years of the eighteenth century"; and that the use of visual aids, such as blackboard drawings, science equipment, models, and "other means of supplementing direct study of natural phenomena," were coming into use almost a hundred years ago.

Concluding Comments

The reviewer of reports of educational research cannot help decrying the common practice illustrated by several studies included in this section of "popularizing" accounts of investigations thru incomplete reporting, in efforts to make them understandable and less formidable to readers untrained in educational research. It seems probable that such practice serves neither the research specialist, nor the lay reader. An adequate account of the essential procedures and technics followed by a statement of implications for the classroom teacher might prove more generally useful.

There is a wider spread of excellence of investigational and statistical technics between the best and the poorest studies here reviewed in the chapters on science at the elementary and junior high-school levels than has been previously evidenced in the studies representing similar periods of time. This increasing difference is due not to decreasing merit in the poorer studies but to marked advances in the major ones.

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CHAPTER IV

Teaching of Mathematics in Grades VII and VIII

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The Curriculum for Grades VII and VIII

UNTIL comparatively recent times there has been little in the mathematics program for Grades VII and VIII which could serve to distinguish it as a definite stage in the development of mathematical power. The reason is largely historical. In the days when most children withdrew from school after the eighth grade, curriculum makers found it expedient to assign the fundamental operations with integers and fractions to the lower and intermediate grades and to use Grades VII and VIII in which to teach the important social applications of number. This traditional program has persisted even tho the conditions for which it was framed no longer exist. In many modern schools the result has been to provide a mathematics program for these grades which strongly resembles a series of social studies units. Important as social applications are, the fact remains that these two years have constituted something of a mathematical plateau marking the termination of the first period of mathematical development and a "breather" before beginning the new work of the high school.

Overcoming the inertia of tradition has not been easy, even in these days popular for curriculum revisions. The mathematics courses of study for Grades VII and VIII have been caught between the demands for an upward revision of the elementary-school curriculum on the one hand, and the "preparatory" demands of the high school on the other. The militant forces at either flank have made it difficult to take a positive position in the development of a distinctive program. Nevertheless progress has been steady, if slow. Schorling (12) prepared a general summary of the important changes in junior high-school mathematics in the last quarter of a century. Trends were cited to show that the junior high school is becoming less concerned with the problem of "preparing the pupil for something" and more with the need of placing him in an environment where he will develop normally.

In the past three-year period one new study, covering the work for Grades VII, VIII, and IX, was added to those reported by Grossnickle (6) in the October 1942 issue of the REVIEW OF EDUCATIONAL RESEARCH. Arenwald(2) reported the reorganization of the mathematics curriculums for the junior high schools in New York City. The new program features (a) the introduction of arithmetic into the IX-A course of study to provide opportunity for correlation with algebra, civics, and other subjects taught in the ninth year; (b) informal geometry in all grades of the junior high school; (c) instruction in algebra beginning in Grade VIII-A and continuing thru Grades VIII-B, IX-A, and IX-B.

The comprehensive report of the special committee of the National Council of Teachers of Mathematics on the mathematics essential for minimal nontechnical army needs is bound to have considerable influence upon junior high-school mathematics. This study, reviewed in Chapter VI on mathematics in the high school, showed a teaching imbalance in favor of computation with serious deficiencies in mathematical understanding, meaning, and application. Suggestions were offered in the report for correcting these shortcomings. The significance of this study is enhanced by the fact that every item recommended in this investigation can be justified in terms of general education. Mallory's checklist (10) offered to teachers and administrators a convenient reference to the mathematical subject-matter reported in the original investigation.

Methods of Instruction

The nonfunctional character of much arithmetic instruction has long been the source of much justified criticism. Several studies reported efforts to meet this criticism. Gorman (5) studied the possibilities of a closer association between science and mathematics by comparing results of instruction based on an integrated plan with the traditional plan of teaching the subjects separately. With small sections of better-than-average pupils no appreciable difference was found between the effectiveness of the two methods under the conditions established. Montgomery (11) reported experiences in teaching a functional unit on the cost of owning and driving an automobile.

Leete (9) and Gordon (4) offered teaching hints for the closer correlation of arithmetic and algebra. These suggestions provide further implimentation to a trend toward a more highly integrated treatment of the two subjects so completely but illogically separated until recent times. Brown's suggestion (3) for teaching percentage without the troublesome "three cases" was another recommendation illustrating the same trend.

Anderson (1) called attention to the interdependence of reading and computation in problem solving and reported his experience with non-academic boys in making problem solving functional. He viewed any difficulty interfering with the interpretation of a problem as a reading difficulty. Group discussions were used to develop a meaningful, "visualized" solution and to lay down the habits of interpretative procedures which are essential preludes to paper-and-pencil work.

Remedial Arithmetic

Two studies showed the value of a systematic and individualized program of remedial instruction in arithmetic. Guiler and Edwards (7) used diagnostic charts, individual graphs of progress, and instruction based upon specific pupil needs with his experimental group, while paired controls were given systematic instruction but without diagnosis. The group instruction based upon individual diagnosis was more effective. Sister

Mary Jacqueline (8) used a highly individualized practice program and finely graded practice materials to help seventh-grade children overcome serious arithmetical deficiencies. The program was largely self-directed and paced in order to capitalize upon any success the children were experiencing.

By way of summary it seems desirable to call attention to the poverty of research in this area during the past three years. Of the twelve articles mentioned in the bibliography only four represent reports of experimentation. Of these four, only three present quantitative data to support their findings. Finally, it may be asserted that none of the three attacked what may be called a vital issue in the field. It is to be hoped that interest in postwar mathematical reorganization will stimulate more experimental activity during the immediate future.

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CHAPTER V

Teaching of Science in Senior High School and Junior College

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THERE has been a decrease in the number of statistical and historical studies in the field of science education during the last few years. Many of the articles that have been published are on the borderline between research and discussion. Tho important contributions have been made that support findings reported previously, there has been relatively little research reported that may be classed as definitely new findings. As yet there have been no careful studies reported on questions raised by the newer developments in curriculum, and there is a sharp contrast between the ideas dealt with in these articles and the current ideas of curriculum workers. The articles reviewed here are grouped under the following major headings: objectives, content and organization, aids to teaching, methods of teaching, interest studies, improvement of science teaching, measurement, vocabulary studies, and trends in science education.

Objectives of Science Education

Hunter and Spore (30) conducted an investigation on a nationwide scale in which they gathered data concerning objectives of science teaching actually being used in secondary schools of the United States. Their findings indicate that the objectives which are receiving much emphasis from leading educators today have not yet had serious consideration by science teachers. As objectives, consumer education and conservation education ranked much lower than expected.

Content and Organization of Science Courses

Wise (60) made a study of the relative importance of principles of physical science for general education. He ranked some 264 principles of physical science. The upper 25 percent included 55 in the field of physics, 8 in the field of chemistry, and 3 in the field of geology. The lower 25 percent included 36 principles of physics, 27 principles of chemistry, and 3 principles of geology. He concluded that: no one specialized area of physical science is more important than all material drawn from other areas; the study of physics has greater value for general education than does the study of chemistry; a relatively large number of major concepts in the field of chemistry do not possess high value for general education; and some principles from the field of astronomy are very important for general education.

Hollinger and others, (27) outlined a course in physical science which was presented to teachers in June 1941. As yet no formal evaluation has

been reported, but the course work has been found stimulating to teachers and pupils. It has been necessary to make more detailed suggestions to teachers in order that pupil activities may be more effective. Grant (22) discussed cooperative science study at Arsenal Technical High School. Brown (8) discussed the reciprocal relationship between mathematics and physics. Since mathematics is a vital tool in attaining many of the understandings in physics, and since physics contributes a background of real experience to mathematics, much is to be gained by a closer working relationship between the two fields. Everote (18) discussed term problems used as an integral part of the chemistry course presented at the Susan Miller Dorsey High School in Los Angeles. Included are problems related to the community such as control of the water supply, science in agriculture, food supply, and so on. The data collected from a follow-up study of 225 students indicated that favorable results are obtained by students taking this type of course.

Stephenson (52) discussed physical science courses for liberal arts students. Van Peursen (58) conducted a survey of quantitative analysis courses in the United States. He found a wide variety of courses with considerable variation in the percentage of class time and laboratory time, and no uniformity in the subjectmatter content of the courses.

Aids to Teaching

Carlson (10) reported on an investigation of the equipment and offerings in the natural sciences in liberal arts colleges. ". . . figures on the teaching budget show clearly that this is not an age of science in colleges and universities. . . ." Many colleges were found to be significantly inadequate in the number of current journals and periodicals of science made available to students. In general, laboratory space and physical equipment were adequate.

Joseph (32) developed a source book of extracurriculum activities in physical science for senior high schools. "In the original document, each of 185 activities is to be found on a single and separate page."

In the area of visual instruction, Graham (21) reviewed research studies and made a sampling study of the use of visual aids in the teaching of general science in the secondary schools of the United States with special emphasis on Kentucky. Miles (37) reported on auditory aids in the teaching of science.

Methods of Teaching

Swan (53) studied the relative efficacy of two methods of teaching agricultural chemistry at the high-school level. He attempted to determine whether farm boys and girls learned chemistry facts and principles and acquired the ability to apply these facts and principles to new problems equally well by the topical assignment method or the discussion method. He concluded that there was not statistically significant difference in the results. Peterson (42) compared the achievement of students in the tradi-

tional high-school physics and chemistry courses, each of one year's duration, with the achievement of students in the integrated courses in physics and chemistry over a one-year period.

Waters (59) conducted an experiment to find out what analytical results would be obtained by "run of the mill" students using two procedures which were as nearly identical as practicable. The essential difference in the procedures was a reduction in the volume of reagents employed and the substitution of a centrifuge for filtration. He found that students obtained more accurate results using the semimicro technics than when using the macro technics.

Interest Studies

Davies (13) investigated college students' interests in biology using an "interest-information" checklist. Students rated each topic on the basis of much interest, mild interest, or no interest. Results are reported for botany and zoology in both graphical and tabular form. Feder and Wright (19) reported an attempt to develop a means of evaluating the effects of different motivations of students in college physics. An attempt was also made to evaluate insight into the subjectmatter as revealed by student ability to apply physics material to everyday life.

De Lano (15) showed that certain concepts cannot be satisfactorily developed with elementary-school students and that grade placement of all important concepts should be made. Phelps (43) investigated the desirability of using city boys to help relieve the shortage of farm labor. His results indicated that supervised farm work experience ". . . can send the youth back to the city with an insight into rural problems that will make him a better citizen for the rest of his life."

Pruitt (45) summarized the results of four studies whose major purpose was to determine the status of science teaching in the high schools of Oklahoma in 1940. The findings indicated: the science teachers were not as well trained as they should be; they were a very mobile group; they were underpaid; and they did not keep professionally up to date.

Siebens and Bartlett (51) indicated the possibilities of enriching the life of the school by close cooperation between the librarian and the science teacher. This included using all the library facilities in developing units of study. Teller (54) proposed enriching science teaching by commemorating November anniversaries of famous men of science. A bibliography of source material is given.

Higgins (26) made an exploratory study in the field of biology in regard to individual abilities. Decker (14) studied the relationship between natural resources and the activities of the people of Colorado. He found that neither the study of resources, nor the study of people's activities, is sufficient for an understanding of community problems. In this study, then, is one more indication that science teachers must deal with social issues as well as with physical forces. Reimann (46) discussed the use of a correlating subject in science teaching, giving illustrations. Using the

topic "cancer" as an example, he showed how mathematics, chemistry, physics, psychology, and sociology are all correlated. Reiner (47) investigated the value of cause and effect in science teaching. Nixon (38) studied the teaching of biology for appreciation. Nordau (39) discussed some of the limitations of objective mental tests as measures of ability to succeed in science. Damerell and Booth (12) discussed technics for improving the teaching of quantitative chemical analysis.

Measurement of Outcomes of Instruction

In the field of science education new emphasis has been placed on the measurement of the results of instruction. Ashford (2) and Hered and Thelen (25) discussed the chemistry tests of the Armed Forces Institute. These reports described the procedure used in standardizing both the civilian and military (secret) forms of the tests, and the procedure for granting credit for high-school and general college chemistry to members of the armed forces. Results from preliminary tryouts are discussed, and some of the implications for instruction are noted.

Calandra (9) discussed the proposed extensions of the college chemistry testing program to include quantitative analysis and physical chemistry as well as general chemistry, qualitative analysis, and organic chemistry. National norms are given for the Cooperative Chemistry Test, Form 1942; the Qualitative Analysis Test, Form Q; and the Organic Chemistry Test, Form S. The scores are further classified on the basis of vocational goals and types of schools and colleges. The future of the testing program is discussed. Adams (1) reviewed some of the critical teaching and testing problems and controversial issues resulting from past practices. "The results of the author's questionnaire gave ample proof that teachers of general college chemistry are interested in new and improved testing devices, particularly as these relate to laboratory achievement." Very little progress has been made in developing adequate testing devices for measuring achievement in laboratory work other than the acquisition of knowledge. Hendricks (24) made a survey of examination practices in general college chemistry. Answer papers of more than thirteen hundred students from eight different colleges were studied, and the validity and difficulty of each question on the examinations were determined. (See article for procedure.) It was found that 44 percent of the questions were either faulty or at most did not contribute greatly in giving desirable information about the students' achievement. ". . . then there is still much to be done if college chemistry examinations are to have a large percent of their questions eligible for the label 'good.'" Duvalle (16) made an evaluation of the standards of chemistry teaching in the universities and colleges for Negroes in the United States. Blick and Andrews (6) made a study of the mastery of general chemistry by trainees in the AST program at the University of Connecticut. Determinations of the simple linear correlations between various standardized tests were also reported. The results indicated a satisfactory degree of mastery of general chemistry, and

showed that the trainees can be judged in terms of the civilian college student. Coefficients of correlation found were comparable to those accepted as evidence of validity for achievement examination. Martin (36) made a diagnostic and remedial study of failures in freshman chemistry at Purdue. At the time of publication, complete results of the remedial measures were not available, altho preliminary results seemed quite successful.

Heidel (23) measured and compared the outcomes of instruction of a general high-school senior science course stressing practical applications and consumer education and a conventional high-school physics course employing the lecture demonstration method and stressing classical applications and problems. Neither course proved effective in bringing about significant changes in scientific attitudes, and the general high-school senior science course proved no more effective than the conventional high-school physics course in attaining consumer outcomes. Everote (17) analyzed modifications of student growth resulting from a course in experimental science in which emphasis was placed upon services rendered by the natural sciences to selected experiences with the social, industrial, and recreational environment. Brewer (7) studied factors affecting achievement and changes in students in a physical science survey course given at Queens College in New York City. He concluded: "Many educators influential in the development of science survey courses have stressed the importance of developing attitudes in students . . . the results of this study suggest that they do not develop automatically with increase of scientific knowledge. . . ." Priesche (44) studied the relationship of certain measureable factors with success in secondary-school physics, and Rosenquist (48) investigated some factors influencing final marks in an introductory course in college biology. Barnes and Mouser (3) developed a test of biological misconceptions for use in the general biology course offered by the general division of the College of Liberal Arts and Sciences at the University of Illinois. They reported their findings on the comparative performance of high-school and university freshmen. Teller (55) proposed some new forms of the recognition test, and Wright (61) applied the modified true-false item to testing in chemistry. Scates (49) discussed some of the limitations of the use of standardized tests by the classroom teacher.

Progress is being made in the more objective measurement of desired outcomes of instruction other than the acquisition of knowledge, such as attitudes, ability to apply generalizations, changes in behavior, and so on. Fleming (20) made an analytical study of certain outcomes of a course for orientation in biological sciences in which he proposed to measure, analyze, and evaluate: the recall of specific information; the understanding of generalizations; the elements of problem solving; and the scientific attitudes developed. "The results and possible implications of this investigation are presented in the form of generalized statements. . . ." Urban (57) experimented with two groups of equated biology pupils in

regard to changes in overt behavior. He concluded: "Changes in overt behavior may be made a practical goal or objective of learning; changes on overt behavior can be estimated by techniques commonly used in educational research; . . . changes in overt behavior seem to be of a more permanent nature. . . ." Ter Keurst and Bugbee (56) developed a test on the scientific method; Owens (41) investigated the ability of students to recognize and apply scientific principles to new situations; Kraus (33) made an evaluation of the pupil-made notebook in relation to certain measureable outcomes in the teaching of general science; Johnson (31) studied growth in ability to acquire and apply facts and principles; and Hoyt (28) developed tests of certain linear hypotheses and studied their applications to educational problems in elementary college physics.

Vocabulary Studies

Schneck and Curtis (50) determined what science terms are most important and should, therefore, be included in a glossary of textbooks of high-school physics. Two hundred and fifty terms are listed which were found most important by the combined judgments of thirteen authors of textbooks and forty-six professors of physics. O'Leary (40) determined what physical science terms appeared in recent magazine articles and compared his findings with similar studies made previously. He found that the physical science vocabulary of laymen's periodicals changes with the times, and he suggested that similar studies should be made at least every ten years. Curtis (11) investigated the mathematical terms used in secondary-school textbooks of science. He studied the relationship between the vocabularies of mathematics and science. Criteria were set up to be used in the selection of mathematical terms. Tables show the distribution of mathematical terms in high-school textbooks of physics, chemistry, general science, and biology and list the different difficult mathematical terms which occurred on an average of three or more times per book or which occurred in half or more of the textbooks of physics, chemistry, general science, and biology. ". . . much the largest average number of different difficult mathematical terms was found in the textbooks of physics and the smallest in the textbooks of biology."

Trends in Science Education and Research on Science Education

Leavitt (34) discussed and analyzed changes in the subjectmatter of teaching science in a school in New York State. Hunter (29) made a survey of trends in the teaching of science covering such items as: interrelation of courses, science enrolments, applied science, laboratory or demonstration, and the noncollege group. Bennett (4) made a study of the trends in the amount of mathematics and science taken in high school. This study covered 7208 high-school graduates embracing a typical cross section of college students. He found the following trends in mathematics:

only a slight downward trend in algebra; a much sharper downward trend in geometry; and a greater variation in the length of high-school courses. He found the following trends in science: much uniformity in the length of courses; a steady decline in the percentage of students who have had high-school physics; a continuously increasing percentage of enrolments in chemistry up to 1935, followed by a slight decline. He found also that botany has all but been eliminated, and that general biology has gained consistently.

Blick (5) reviewed recent trends in research on science teaching. In agreement with the findings in this review he reported that there have been fewer studies made in the teaching of science in recent years; studies that have been reported are in general of better quality; there appears to be a trend away from the historical type of research; and that there has been an increasing emphasis on procedures for defining student need and on procedures for serving them.

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CHAPTER VI

Teaching of Mathematics in High School and Junior College

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AN unusual amount of attention was given to arithmetic in the high schools and colleges during the period under review. Data were published indicating that many high-school and junior college students were unable to solve arithmetic problems of an elementary sort. Altho many schools established remedial or "refresher" courses in mathematics, relatively few studies of the effectiveness of such work have thus far been published.

Arithmetic in High Schools

Blair (5) reported the results of a nationwide survey of remedial programs based on replies to a letter sent in 1940 to 1090 principals of public high schools in towns whose population was 20,000 or more. Replies from 379 schools in thirty-eight states included 166 which described work in remedial arithmetic. They revealed that it is generally handled in one or more of the following ways: (a) remedial arithmetic classes; (b) special curriculums for pupils of low mental ability; (c) general mathematics classes; (d) special arithmetic classes for high-school seniors; (e) courses in commercial arithmetic, business arithmetic, shop arithmetic; (f) teachers in regular classes. Of these the first is most common, altho the length of time pupils take the remedial work varies greatly. Tests on arithmetic fundamentals are widely used to select pupils who are to take the remedial programs.

Stimulated by unfavorable comments on the results of an arithmetic test given by the Navy, Christoffersen and Wittich (8) gave the same test to graduating seniors in a large high school. Later a twenty-five minute "chalk talk" on the fundamental processes and a parallel form of the test were given. The median score increased from 73 percent on the first test to 88 percent on the second, leading the authors to suggest that poor retention rather than the quality of the first teaching explains the low scores on such tests.

In more detailed studies Guiler and Hoffman (21) found serious arithmetical deficiencies among 238 ninth-grade pupils in one school in Ohio. On the basis of an arithmetic test they selected 108 students for remedial work. Of these, fifty-seven were enrolled in algebra and the rest in applied mathematics. For eighteen weeks, thirty-five minutes from each of two periods of the algebra class were allocated to systematic instruction and practice in arithmetic based on an individual diagnosis of difficulties. The other students took these courses or junior business training in the usual way. Mean scores on the final retest were 32.7 and 25.8 for the remedial and nonremedial groups, respectively, representing gains of

10.2 and 2.0 points. In a later report (20) the study was extended. Tests were given to 836 ninth-grade pupils in four school systems and results published in the form of error-quotients show the extent of arithmetic deficiencies of various types. Also reported (20, 22) were data from one city showing that algebra and remedial arithmetic taught together as indicated above give better results, in general, than algebra alone. The achievement in algebra as measured by the Ohio Every Pupil Test in Elementary Algebra prepared for April 1943, was approximately the same for each of two groups of about fifty-seven students. The algebra and arithmetic group, however, made an appreciable gain in arithmetical computation abilities, while the group which studied only algebra made practically no gain in arithmetic.

Brueckner (7) conducted an extensive study which included data on the effects of remedial treatment. He obtained data from ninety localities in thirty states by giving a thirty-item test of abstract arithmetical computation. The mean number of correct responses in Grade XII ranged from 8 to 25 in the different schools, the mean of the distribution by schools being 17.3 or 57.7 percent. This was compared with the means of certain groups in the University of Minnesota, namely seniors in the College of Education (18.8), preflight students (19.4), and army engineers (25.6). Seven schools gave the test to all high-school students. Altho there seemed to be a small gain in achievement from grade to grade in five localities, there was no consistent trend.

Brueckner's original test was timed at sixteen minutes. The senior class of one high school was given an equivalent form one week later and was allowed twenty-five minutes. As a result the mean was raised from 12.5 to 19.6. On the first testing, no marked differentials in achievement in terms of the number of courses of mathematics taken were found except in the case of students who had taken three or more courses. On the second test, a steady rise in the mean occurred with each added course. One group of seniors was given thirty minutes of intensive remedial work for each of four days. This group thereby raised its mean score from 11.8 to 20.1. Brueckner then instituted a similar remedial program for all senior students in another school, and these students raised their mean from 14.0 to 19.3.

Orleans and Saxe (30) prepared a test which covered arithmetic computation, problems dealing with simple business situations, arithmetic information, definitions of business terms, and simple clerical situations. This was given in February 1941, in ten high schools of New York City and in seven other cities, a total of seventy-seven classes and 2281 students being involved. In June, 1460 of the students were retested. The students were enrolled in elementary business training, commercial arithmetic, bookkeeping, or in the academic curriculum. Data on intelligence, achievement, and on the frequency and types of errors made, were extensively reported and analyzed. The interpretations of the authors may be sum-

marized by saying that they regard the achievement shown as low and very unsatisfactory, and they attribute it to a relative lack of understanding or meaning in the prior arithmetical experiences of these students.

Arithmetic in Colleges

Results typical of those found in numerous informal studies were published by Volpel (36). He gave an inventory test including both algebra and arithmetic to sixty freshmen and sophomores in Alma College. His error count shows a wide range of success with the twenty-five different items, but it should be noted that many of the items seem to involve somewhat unusual features. Wilson (38) gave tests on the simplest processes of arithmetic (e.g., addition) to students in Boston University for several years with results showing the need for remedial teaching on the college level. Mohr (28) gave the advanced arithmetic test of the Metropolitan Achievement Test battery to eighth-grade pupils and junior college students in San Francisco. The achievement level of the college students was shown in terms of the percent of correct responses for various types of abilities. Mohr also selected from his subjects a group at each level comparable as to sex, intelligence, and "equivalent age." Data from these groups indicate that four years of instruction in high school, including usually two years of mathematics and one of science, were able only to offset the loss in most arithmetical abilities due to disuse and forgetting. The junior college students had, however, developed significant superiority in the ability to read graphs, handle denominate numbers, do mensuration and geometry, apply percentage, and solve equations.

Orleans and Saxe (29) gave a test of ten verbal problems in commercial arithmetic to students in the School of Business and Civic Administration of the College of the City of New York. They reported data on achievement and errors, and attributed low achievement to lack of familiarity with business computational processes and terminology, lack of appreciation of the reasonableness of a result and the need for checking, and similar factors. They found that for these students arithmetical errors were of relatively minor importance.

Guiler and Rush (22) reported on investigations with 1063 college freshmen and 142 teachers in service, supporting the generalization that extensive arithmetical deficiency exists at these levels. A total of forty-nine students completed a remedial project in less than two months, thereby raising the median score of the group from thirty-four on the initial to forty-six on the final test. Data were reported also in terms of certain specific phases of computation, intelligence level, and error quotients.

The methodology of all of these studies was simple. An arithmetic test was given and the results were analyzed. In some cases auxiliary data in the form of intelligence quotients or courses taken were obtained, and if so the students were classified accordingly and these results analyzed. The recognized limitations of data from a single school led some of the

investigators to extend their populations to include other groups. Data derived from error counts were used extensively. In those cases where the effects of remediation were studied, the conclusions were based on results of a retest. For the most part, the tests used measured computational skills of a simple sort with abstract numbers, and there was little or no discussion of their validity and reliability. In every case the interpretations drawn by the authors implied that in general the level of achievement shown was low or unsatisfactory. These judgments were essentially subjective, since objectively determined norms apparently were nonexistent for the tests used as they were in these studies. It appears that the determination of adequate norms for valid and reliable tests of arithmetical ability at the senior high-school and college levels would be desirable. Such tests would facilitate the selection of students needing remedial treatment, controlled studies of what constitutes an effective remedial program at these levels, and study of the progress of a possible gradual raising of the arithmetical abilities of senior high-school and college students.

Prognosis and Diagnosis

The problem of predicting achievement and related questions has continued to receive attention in recent years, particularly at the junior college level.

Guiler (18) studied the predictive value of the Iowa Algebra Aptitude Test (revised edition), the Christoffersen-Rush-Guiler Analytical Survey Test in Computational Arithmetic, and Form A of the Breslich Algebra Survey Test, all given to seventy-five students in the ninth grade. The criterion was scores on Form B of the Breslich Algebra Survey Test at the close of the first semester. Product-moment coefficients of correlation between the criterion and the other tests were found to be .775, .707, and .731 respectively. The coefficient of multiple correlation between scores on the criterion and the other three tests was .845. Altho these results are high, they were obtained from only one school. Guiler also summarized a number of related studies.

Stein (33) administered the Cooperative Plane Geometry Test, Form R, to 260 students in the eleventh grade at Winnipeg, Canada, and used the scores to divide the group into thirds on the basis of achievement. He also administered other tests (for the most part standardized) to obtain data on twelve traits designated as (a) general intelligence, (b) spatial relationships, (c) linguistic ability, (d) quantitative ability, (e) total score on the ACE psychological examination, (f) arithmetic problem solving ability, (g) arithmetic computational ability, (h) reading comprehension, (i) study habits, (j) logical reasoning ability, (k) symbol manipulation, and (l) teachers' estimates of success. Using analysis of variance technic, he found the differences between the groups on these traits to be, in general, statistically significant at the 1 percent level. In the case of

spatial relationships and study habits, however, the differences between the average and poor achievers were not significant at the 5 percent level. He found that the factors most closely related to success were general intelligence and the ability to manipulate symbols, as in algebra. He found a multiple correlation coefficient of .665 between the estimated criterion scores and the intelligence and algebra factors.

Goddeyne and Nemzek (16) reported on a study of the relative prognostic value of the Lee Test of Geometric Ability and the Orleans Prognosis Test. The chief criterion used was scores on the Cooperative Plane Geometry Achievement Test obtained for 164 parochial students in Detroit. Coefficients of correlation between pretests and criterion were in the neighborhood of .60, and the results tended to favor the Lee test, but by insignificant amounts.

Gere (15) described the construction and use of a mathematics placement test for the junior college level. Cox (10) and Harper (23) described the testing program used for guidance at the University of Nebraska, reporting coefficients of correlation between scores on the classification examination and the final examination, and also between the former and course marks, as well as certain additional data showing the distribution of scores on the same final examination taken by students taught in different ability groups determined on the basis of the pretest.

Vaughn (35) investigated the value of a scholastic aptitude test developed by Crawford at Yale when used to predict success in colleges of engineering. The part of the test designed to measure mathematical aptitude was found to correlate higher than any other with the freshman average grade, yielding a coefficient of .51 for 643 cases. There was, however, rather wide variability among several different institutions. In a later progress report (34) he discussed the prognostic value of certain new preengineering inventory tests compared with the psychological examination of the American Council on Education. He obtained multiple coefficients of correlation of .69 and .67 at two different institutions between the new tests and grade point averages, and his data indicated that for this purpose the new tests are superior to the ACE examination. He also exhibited in tabular form the positive relation of the scores to the number of half-years of mathematics studied in high school.

Kassock (26) described work in placement at the University of Oregon using multiple regression equations with as many as five independent variables. The use of a resulting placement chart reduced the drop-outs or changes of courses after registration from 29 to 9 percent. A discussion of a program developed since 1927 at Iowa State College was reported by Robertson (31). He published placement test items and data associated with each obtained from 704 students in 1941. Using a linear multiple regression equation, he found that 44.6 percent of the predicted scores agreed with the obtained scores, while 84.5 percent either agreed or differed by at most one letter grade.

Keller, Shreve, and Remmers (25) continued their diagnostic testing program at Purdue University and reported on some of the results. They compared scores obtained from experimental and control groups of 130 or more students each. Both groups were given the same tests, including a psychological examination, the Iowa Mathematics Training Test, the Keller-Shreve-Remmers Number Technique Test, the Purdue Mathematics Training Test, and eight achievement tests in trigonometry. The groups were shown to be quite comparable at the beginning of the course in trigonometry. The experimental group, however, was given seven periods of remedial instruction in algebra. They were then given tests equivalent to the preliminary tests in difficulty and type of material, and the mean gain was found to be approximately 40 percent. Moreover, the mean scores of the experimental group on five of the eight trigonometry tests were higher by an amount significant at the 5 percent level in one case, and at the 1 percent level in the other four cases. On three of the tests the differences were not significant. In terms of the distribution of semester grades the results also clearly favored the experimental group.

The evidences of continued interest in prediction and guidance at the college level are encouraging, but the results of many studies by correlation methods suggest that further progress in this direction will depend upon studies of personality factors which may prove difficult to quantify.

General Mathematics in Colleges

The most comprehensive study to date of the general mathematics movement in colleges was completed by Brown (6). He made a survey of the pertinent literature, secured questionnaire results from 458 colleges offering general mathematics in the United States, analyzed more than fifty general mathematics textbooks, recorded observations of fifty classroom recitations, and analyzed opinions of 1500 students enrolled in classes. He traced the development of courses of this type since about 1892 and commented upon several factors influencing it. He found that the objectives of general mathematics as indicated by (a) committees of specialists in the field, (b) authors of the textbooks, and (c) teachers of the subject fall into three categories. The purposes of one group are college preparatory in nature; the aims of another group concern the cultural and social development of the individual; in the third group the objectives include a combination of these two functions. Brown investigated the provisions made to meet these objectives and found that in both the preparatory and the cultural-preparatory courses the content, style of presentation, and emphasis given to topics were substantially identical, but these differed markedly from the offerings in the cultural type. In evaluating the success of these courses, he found that in general (a) the objectives of the preparatory type are largely being realized, (b) the realization of the dual aims and purposes of the cultural-preparatory type are being seriously questioned, and (c) cultural general mathematics, while not entirely

satisfactory, is more nearly meeting the needs of the terminal students in mathematics than the traditional offerings.

Miscellaneous Studies at the College Level

Barnes (1) investigated the effect of the study of eight or more semester hours of college mathematics on the scores of the ACE psychological examination. He found no significant differences in test scores between forty such students and seventy-five other students who had completed two years of work without taking college mathematics. Erskine (13) discussed the use of an index number for evaluating the results of one teacher with different classes (or of a department) in terms of successes and failures made by students on individual test items. Bergen (3) published data on the relative achievement of engineering and other students judged by letter grades obtained in different courses. His data indicated that the liberal arts students in one junior college, altho they had the least previous experience with mathematics, made the best records in college mathematics courses taken in common by students of various curriculums. No data were given on differentials in general ability which may have existed among the groups in the several curriculums. Hassler (24) described a study of the grades of 677 students in the second semester of calculus who had taken the first semester under eleven different instructors. He showed that whether the teacher was the same or different for both semesters made a negligible difference in the grades received.

Bennett (2) compiled data on 7208 high-school graduates who were enrolled in the college of education of Ohio State University. The period covered extended from 1883 to 1943, and after the year 1920 samples of 250 or more cases were used. There was only a slight decline in the percent of students who had taken algebra, but there was a much sharper downward trend in geometry. Of 769 graduates of 1920 or earlier, 745 or 96.9 percent had taken some geometry in high school. By 1943, the percent had dropped to eighty. There was also a definite tendency to take a smaller number of units of mathematics in high school. Bennett regarded the gradual reduction of entrance requirements which occurred during this period as a co-variant rather than a causal factor of the decline.

Interests and Attitudes

Fortune Magazine (14) published results of a survey of opinion among high-school students. The data indicated that mathematics courses were liked *best* among high-school courses by a higher percent of students than was found for any other field, and also these courses were liked *least* by a higher percent of students. It also appeared that those disliking English, languages, and history are devoted to mathematics and the laboratory sciences, and vice versa.

An interesting study of the relationship between attitude and achievement was reported by Billig (4). He secured essay responses of an atti-

tudinal nature from students in commercial arithmetic. He divided his ninety-two usable cases into three groups on the basis of their "term average" in the course, and found a statistically significant positive relationship between favorable attitude and achievement. He used fifteen judges to classify student statements and developed a scale for measuring attitude toward arithmetic which has potential usefulness in guidance.

Controlled Studies of Curriculum Modifications

Willits (37) gave an excellent analysis of objectives of ninth-grade mathematics in the light of modern conditions and centered upon problem solving as the major ability to be developed. He also described an experimental study in which one group of about forty students of average ability was given a course in which the usual logical organization of mathematical content was replaced by a set of twenty-four more general problem situations. Instruction was focused upon the process of problem solving, including the analysis of the situation, the collection and analysis of data, the drawing of conclusions, the making of generalizations, and similar aspects. Mathematical abilities developed included the recognition of and the expression of quantitative relationships by verbal statements, tables, graphs, formulas, and associated concepts and skills. A second group of about the same size, slightly superior in general intelligence and arithmetic ability, was used as a comparison group. These students took the regular course of study in algebra under another instructor. The Columbia Research Bureau Algebra Test was given to both groups, and it appeared that the first group had developed a slightly better than average ability to solve verbal problems at a slight sacrifice in ability to handle mechanical aspects of algebra covered by the test. Willits also prepared a test to measure certain abilities more closely associated with problem solving. This test was given as both a pretest and a final test. Differences between the means for the two groups were not significant on either the pretest or the final test. However, the mean gain of the experimental group was significant at the 1 percent level, but the small mean gain of the control group was not significant. Data on the interest of both groups of pupils in mathematics showed that the experimental group gained and the comparison group lost interest during the year.

Cook (9) described a one-semester study of the teaching of logical reasoning in connection with plane geometry, using nongeometric reasoning situations. One group of 326 students under eight teachers was given the modified course, while another group of seventy-six pupils under three different teachers followed the usual classroom procedure. Data on intelligence and from a pretest battery covering five aspects of logical reasoning showed the groups to be initially comparable. The mean of the experimental group on the final test exceeded that of the control group by an appreciable amount, but data on which to judge the statistical significance of the differences were not reported. Both groups were given an

achievement test in plane geometry with a total score of 193 points. Altho the difference of the means favoring the experimental group (mean, 137.8) and the control group (mean, 136.5) may or may not be statistically significant, it seems evident that in this study the allocation of approximately one-fourth of the time to nongeometric material had no adverse effect on geometric achievement.

Shaw (32) set up two equated sections in ninth-grade general mathematics on the basis of intelligence and first semester achievement. With one section he used goal sheets on which students copied the goals for each unit and checked them off as progress was made. Scores from five tests showed superior gains were made by this group, and there were indications that students of lower intelligence profited more than others.

An Important Curriculum Report

A committee of the U. S. Office of Education (27) which worked in conjunction with the Civilian Preinduction Training Branch issued a significant report on essential mathematics for minimum army needs. This report was based on a checklist which was used to obtain reactions from ninety-six training officers during informal conferences, and item-by-item checks from 178 officers serving as instructors in basic training. The mathematics outlined in the report was thus that actually needed by nearly all men in basic training. The report also contained an excellent discussion of the point of view and the emphasis to be followed, stressing the role of applications and the importance of meaning. Finally, it contained a set of specific suggestions with respect to instruction and advice relative to setting up the instructional program.

Studies of Concepts, Vocabulary, and Equipment

Cronbach (11) prepared a test in which each of fifty-five true-false items dealt in some way with the function concept. He obtained responses on this test from a representative group of forty-one teachers of mathematics and analyzed the results. He found considerable variation and some inconsistencies among the teachers with respect to their acceptance of various subconcepts or aspects of the major concept.

Curtis (12) reported on the mathematical vocabulary used in science textbooks. Difficult words were defined as those not in the first 6000 of Thorndike's 20,000 word list. A criterion containing six descriptions was used to identify the *mathematical* terms from more extensive lists taken in previous studies from thirty-three textbooks of science. By far the larger number was found in physics, where the average number of different difficult mathematics terms in nine books was 159, which was 11.3 percent of the average number of difficult words per book. Curtis also gave a list of the difficult terms occurring on an average of three or more times per book, or which occurred in half or more of the books.

Gorman (17) prepared a checklist of seventy-five items of equipment suggested in books and other sources for use in mathematics classrooms.

He obtained opinions from thirty-two authorities on the teaching of mathematics concerning the desirability of each item. He found that at the senior high-school level sixty-seven items were considered highly important or desirable by the majority of the authorities.

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CHAPTER VII

Teacher Education in the Natural Sciences and Mathematics

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THE emphases that seem to pervade recent reports of studies in teacher education, both general studies and those concerned specifically with the education of teachers of science and mathematics, are on the importance of continuity in teacher preparation and growth, the necessity for integration of experiences in teacher education, the study of the community, and the function of the teacher as an agent of community betterment.

These emphases are obviously interrelated. A concept of education as a continuous process involves a realization of the interdependence and interaction of all experiences. The integration of their experiences can be done only by those who are undergoing them. People need help in achieving such integration, and the study of the community is being found effective as a means of organizing experiences. Community study necessarily raises the questions of community improvement and the responsibility for it.

The Need for Continuity

The report of the National Committee on Science Teaching (18), gave evidence of the difficulty of identifying a line of demarcation between preservice and in-service teacher education in science. In a pamphlet publication of the Commission on Teacher Education, Evenden (11) pointed out a growing recognition of the continuous nature of the teacher education process which is leading to fundamental changes in curriculums for prospective teachers and in educational programs for those already teaching. He stated also that during the last two decades there has been a much greater and more rapid increase in the quantities and kinds of knowledge and skills considered important for teachers than in the length of the preparatory period. Consequently much that is important has had to be postponed from the preservice to the in-service period of teacher education. Evenden indicated further that as a result of the war, new demands have been made on teachers, requiring many sorts of adjustments and calling attention to the need for more effective preparation and for better provisions for growth while teaching.

There is documentation of such need in the statement of purposes of the commission (9). A summary of the characteristics of the teaching profession—actual and prospective—revealed that altho the median age of teachers is probably still below thirty-five years, the average age is steadily increasing. This finding led to the conclusion that not only should prospective teachers be afforded an excellent and extended education,

but that teachers in service for many years should be aided to grow in professional competence.

This volume also contains an analysis, based upon study of American life and ideals, of the qualities desirable for teachers in America. The analysis was presented as having implications for the organization and curriculums of colleges preparing students to teach and for the fostering of continuous professional development after graduation.

In its report on the in-service education of teachers (19), the commission defined the continued education of teachers as steady growth in the capacity to teach, broadened understanding of human development and human living, and growth in the capacity to work with other people—classroom teachers, administrators, parents, community leaders, and children of various ages. Armstrong, Davis, and Hollis (3), reporting procedures in the colleges and universities associated in the cooperative study of the Commission on Teacher Education, concluded that teacher education is legitimately concerned with everything about the individual from the time he decides to prepare for teaching, during every stage of his preservice experience, and thruout his period of activity in the profession. They predicted increasing attention to in-service teacher education in the immediate future. They found, furthermore, that an institution that attempts to serve active teachers is likely to find demonstrable improvement in its programs of preservice education.

A general conclusion from the two studies just cited was that, altho excellence in teacher preparation is and will continue to be essential, its fruition in effective teaching depends to a significant extent on the opportunity and challenge that inhere in the school situation.

Attempts To Promote Continuity

For continuity in teacher education to be realized, the gap between the thinking of school personnel and college people must be decreased. The two groups have not in the past recognized their common interests. The first step toward such recognition has been the cooperation between college departments of education and active teachers in the directing of the practice teaching experiences of prospective teachers. The report, *The College and Teacher Education* (3), contains instances in which school and college instructors have become aware of their mutual concern with teacher education. For example, the faculties of Washington State College and Eastern Washington College of Education were interested in working in the summer workshops of the Spokane school system because for many years their education students had been observing and practicing in the Spokane schools. Following the first workshop experience, a committee consisting of both school and college people undertook the revision of the college extension courses to fit them more closely to the educational needs of the teachers for whom they were offered.

Since December 1938, the University of Nebraska has been carrying on experimental work designed to further the professional development of

active teachers. Group work has been conducted in in-service education centers by a university coordinator, whose task it is to bring such resources as the services of experts, books, and equipment to bear on the needs of the teachers in attendance at each center. The report revealed that the Nebraska program ramifies widely and significantly thruout the state, and that not only does it serve active teachers and local communities, but thru it campus courses for prospective teachers are becoming more meaningful and preservice education is gaining in vitality.

Integration of Experiences

Evenden's survey (11) showed a perceptible tendency on the part of educators to recognize education, and therefore teacher preparation, as dealing with large related areas of experience rather than as consisting of credit hours of physics, mathematics, history, and the like. Some educators were found to be thinking in terms of subjectmatter groupings such as the humanities, the arts, the sciences, and the language arts; others to believe that all organized bodies of knowledge are properly conceived as resources to be drawn upon in preparing people to live with satisfaction to themselves and to society. Evenden stated, however, that integrations of this kind have not yet been incorporated to any great extent into programs for the preparation of teachers.

Progress Toward Integration

The Columbia University Cooperative Program (12) was planned to progress toward integration. Three approaches were used. The first was that of developing a close relationship between professional education and liberal arts study. This approach had two aspects: (a) that of helping the student become aware and critical of his own educational experiences, whether in or out of school, and (b) that of providing him with firsthand acquaintance with the problems and possibilities of the work of the teacher. The second approach was that of working out a meaningful continuity among the various elements of professional education. Courses in education are frequently at least as unitary as courses in any of the liberal arts, and as a result may be highly theoretical and remote from actual teaching problems. The third approach was thru the establishment of an effective relationship between undergraduate work and the graduate study which immediately followed it in the program.

The Columbia University program was carefully evaluated during its three-year demonstration period. Among the results which were convincingly established were gains in the integration of the various phases of teacher preparation, including subject fields and areas of professional education.

A program for the preparation of teachers at Syracuse University (8) was set up on three basic principles: (a) that theory and practice should be integrated at every step of the learning process, (b) that subjectmatter should be selected in terms of clearly defined objectives and should be

integrated around concrete problems, and (c) that a wide range of learning activities should be included in the preservice curriculum. The science program that took its departure from these principles required the prospective science teacher to acquire first a background of liberal arts study in which the work in science was distributed among botany, zoology, chemistry, physics, and geology. Professional study of science education was built upon this background and was concerned with the character and function of science materials, the development of teaching materials, the presentation of teaching materials, and the evaluation of teaching outcomes.

The Syracuse University program was frankly experimental. Those responsible for it and those who studied it from without concluded that it was sound as to basic principles and general directions, and that all the evidence accumulated indicated its marked superiority over the former more traditional program.

At the Wisconsin State Teachers College at Milwaukee, it was felt that the existing program failed to provide for the general cultural development of the students, a failure believed to result in large measure from a lack of integration of subjectmatter. An "area curriculum" was therefore set up, which consisted of required broad-fields courses in the junior college years. One of the areas was that of the physical sciences, another that of the biological sciences. An account of the development of the area course in the physical sciences is included in a report of the Commission on Teacher Education (3). The course attempted to integrate the fields of physics, chemistry, mathematics, geology, and astronomy. At first the staff divided the time allotted among the several subjectmatter fields, selecting titles for the year's lectures and arranging these in logical sequence. The attempt to integrate the work was made by dividing the class into discussion sections, each with a staff member as leader. As the work progressed, the focus of integration came to be seen in the life purposes of the individual students, and changes were made in the direction of greater student participation.

One of the checks on the work of the area courses was the administration of the Cooperative General Culture Test to matched groups of students in the area curriculum and in the traditional curriculum. The average scores on the total test were at the 78th percentile for the experimental group and at the 65th percentile for the control group. The experimental group consistently outranked the control group on all subdivisions of the test: in science, the rankings were 82 and 54, respectively, and in mathematics they were 64 and 54. When the test was repeated with new matched groups the next year, similar results were obtained.

Studying and Serving the Community

The fundamental role of education is to integrate the student with his community and to acquaint him with what is known. It is therefore no innovation in educational theory to recommend that teachers possess

knowledge of facts about communities and of methods of getting such facts, as well as some desire to use them for the welfare of human beings. Stress on community study in programs for the education of teachers is, however, relatively new.

There is a great body of information, pertinent to community improvement, with which teachers and students are yet unacquainted. Ivey (14), reporting for the Southern Committee on Regional Study and Education, indicated the importance and nature of southern regional resource education, and appraised existing sources and methods. He concluded that an amazing development of the South is possible thru general understanding and participation, that a wealth of material is available for use, and that this material must be integrated by state and regional agencies. The results of modern research in the physical, natural, and social sciences can be brought into the schools and thru them into the communities. But this can be accomplished only when the teachers in the schools are interested and are able to develop and use new technics. Any effort to translate research for public-school use depends on the abilities, knowledge, and attitudes of the classroom teachers. Ivey concluded that for teachers to utilize more effectively the community resources available to them, there must be new procedures in preservice education and new emphases in in-service programs.

Procedures for Preservice Community Study

Two recent reports suggested procedures for preservice community study. Dunlap (10) analyzed ways in which prospective teachers may explore communities served by the schools in which they observe and practice, and the means by which individual guidance during student teaching experience may point up the opportunities for teachers to become functioning members of their communities. Richardson (20) proposed for prospective science teachers an extended series of experiences and studies directed toward an understanding of school and community relationships and problems and competence in dealing with them. The experiences were chosen in the light of the students' backgrounds and of the types of communities into which they go to teach.

Community Study by Active Teachers

The Commission on Teacher Education collected and interpreted reports of community study by experienced teachers. One report, included in *The College and Teacher Education* (3), described work in a Nebraska center, where evaluation of the curriculum in a town of 360 inhabitants had revealed a marked deficiency in the health program. To change this situation, the school first brought the problem to the attention of the community, working thru the parents' organization and the local press. Study units in health were planned by students and teachers together. Annual health examinations of all pupils were introduced. The entire community became health conscious.

Prall and Cushman (19) discussed at some length a countywide study of community problems, which was carried out cooperatively by teachers in Colquit County and Moultrie, Georgia. Eight working groups were organized, three dealing with health (control of hookworm, typhus fever, venereal disease, and dental decay), three with recreation, and two with studies of homes and housing. The descriptions of their activities revealed two general pervading purposes: a relatively continuous desire to improve health conditions and to make local living more attractive and satisfying, and an effort to see more clearly how to meet the needs of their students. They revealed also the effectiveness of the three-year project in improving community conditions; in changing curriculum procedures, teaching methods, and educational philosophies; in increasing social understanding; and in providing for the practice of individual initiative.

Another cooperative program of community study was reported from Des Moines, a program which was carried on simultaneously in several directions. Prall and Cushman (19) called attention to five of its features: (a) the work was conducted in such a way as to foster the emergence of new ideas; (b) new groups were encouraged to start work on an independent basis, but these quickly joined in with the general program; (c) responsibility for the several projects was delegated to subcommittees of the large planning committee; (d) the role of lay leaders was as important as that of school people, and both groups came to see the city's agencies as partners in the education of youth; (e) the school administration followed the policy of leaving the project to the initiative and leadership of classroom teachers and laymen while maintaining an active interest in developments. The next step in the Des Moines program was seen to be the task of educating teachers and the people of the community generally to the possibilities of pupil participation in community study and curriculum planning.

Such cooperative programs are evidence of the stimulation of group thinking and its culmination in group action. Other instances of group thought and action in programs for teacher preparation and teacher growth were reported by Study (21), Carothers (7), and Armstrong (2). Another case in point is a community study conducted in Indianapolis as a project of the Arsenal Technical High School (5, 13). Particular attention was given to the implications of the study for science teachers, which led to changes in the direction of broadening the science offerings of the school.

Extending the Education of Science Teachers

A long-term project for improving the education of science teachers was conducted by the Bureau of Educational Research in Science of Teachers College, Columbia University (4, 5, 6, 17). Beginning in 1939, workshops for science teachers were held each summer; the first marked the beginning of a period of cooperation between the bureau and certain of the

schools represented by the participants. The representatives of these schools brought their problems to succeeding workshops. Members of the bureau visited the schools during the academic sessions, advised with administrative and supervisory officers and with teachers, and assisted with the initiation and development of new procedures. The workshops represented an effort to supply experienced science teachers with opportunity for continued personal growth and professional development, to make it possible for such teachers to meet and share experiences with others who teach at different levels, who have specialized in other sciences, and who come from different regions.

These workshops operated on the assumption that community study, together with study directed toward an understanding of the youth to be taught, affords a sound basis for the exploration of the several fields of scientific knowledge to identify information pertinent to understanding and attacking people's problems. During 1943, such exploration was concerned with aspects of the physical sciences related to housing and to specialized training for war service, and with aspects of the biological sciences pertaining to human nutrition, communicable diseases, and interracial relations. In the 1944 workshop, emphasis was on scientific knowledge in its relation to the technological use of materials and energy and to technological developments affecting agricultural production. There were three recognized aims: (a) to help the participants develop a philosophy of science teaching in accord with the emerging aims of general education; (b) to help them become aware of the place of science in society; and (c) to help them make their knowledge a part of their working equipment. Evaluation by the members indicated progress toward each of these goals (6).

Proposals for the Education of Science Teachers

At the University of Texas committees were established to work on appropriate curriculums for high-school teachers in several areas, including the areas of natural science and mathematics. The report of the mathematics committee, which was appointed later than that on the natural sciences, has not yet been made generally available. The report of the committee on the natural sciences was summarized in *The College and Teacher Education* (3). This committee consisted of the deans of the college of arts and sciences and the school of education, and professors of botany, chemistry, geology, physics, zoology, and secondary education. Its first activity was a survey of conditions in high schools, which brought out the facts that, of the 1800 active science teachers in Texas, nearly half were in schools enrolling fewer than 150 students, and that a typical teaching schedule included courses in general science, biology, chemistry, physics, and mathematics or history.

Altho the committee members seriously considered the possibility of establishing broad courses in the physical, biological, and earth sciences

for prospective teachers, they finally proposed instead a curriculum emphasizing a greater range and less concentration in special subjectmatter courses than they had previously obtained to the end that each science teacher would have an acquaintance with five sciences, a fuller knowledge of two of these, and further work in one. They also recommended the establishment of a seminar on teaching the natural sciences, to be concerned with integration and synthesis of the several sciences for purposes of secondary-school teaching. This synthesizing seminar was to be conducted by a specialist in science education who would also direct the long-term task of revising specific science courses and serve as liaison officer between high-school and university personnel.

Working at Ohio State University, Richardson (20) secured objectives for the preparation of science teachers (a) from a considered statement of a philosophy of education, including a discussion of the psychology of learning; (b) from a synthesis of opinions of experts relative to the education of science teachers; and (c) from an examination of the present scene in science teaching, including trends in enrolment, organization of textbooks and laboratory manuals, and preparation and information of science teachers. He made a survey of experimental approaches to teacher education and developed an interpretation, in terms of science teaching, of "factors in competency for teachers" prepared by leaders in Ohio education. Out of this background, Richardson proposed a general plan of college curriculum organization and functioning having five areas: personality development, professional competency, community study, general science information, and special science knowledge. The area of general science was concerned primarily with the development of a comprehensive world picture and of understandings of science applications in daily living. The area of special science was organized in terms of "functional units," such as the conservation of resources and the production of synthetic materials.

Recommendations Relating to Legislation

The Cooperative Committee on Science Teaching (15, 16), composed of representatives of the American Association of Physics Teachers, the American Chemical Society, the Mathematical Association of America, the National Association for Research in Science Teaching, and the Union of Biological Societies, found that the certification requirements for secondary-school science teachers were low with regard to subjectmatter, and that teaching combinations were chaotic and not to be justified on the basis of teachers' preparation. The committee accordingly recommended a policy of certification in closely related subjects, specifically in any three of the following: biological science, chemistry, earth science, mathematics, and physics.

A committee on the Teaching of the Basic Sciences (1) arrived at the following conclusions from a review of the results of recent studies:

(a) there is a conspicuous lack of training in the physical sciences in secondary schools, owing to the fact that more than half these schools have six or fewer teachers; (b) some of the best science teaching in smaller high schools is being done by teachers of agriculture whose time is prorated; and (c) those now teaching science in many states are poorly prepared in their respective subjects. Many teachers were found to teach three, four, or even more subjects which may be almost entirely unrelated, and science teaching often was assigned to individuals for whom science was only a minor subject in college. This situation could be remedied by certification of science teachers in comprehensive areas, such as a combination of the physical sciences with the biological sciences or with mathematics and geography. But teachers trained in such areas are also potential candidates for industrial positions at higher salaries.

The committee proposed, therefore, that existing legislation relating to vocational and technical education be amended and future legislation be formulated to include provision for the sciences (including mathematics) basic to such fields as vocational agriculture, trades and industries, home economics, and distributive occupations. Such provision would have two major effects: (a) standards set up by state departments of education in cooperation with the U. S. Office of Education would have to be met; and (b) since the effectiveness of engineering, technical, and vocational education and training is largely dependent on the quality of preparatory education in mathematics and science, programs of teacher education under acts supplying federal support would have to include provision for the preparation of science and mathematics teachers.

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